

Flow 101

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Presentation Outline

- Measurement Techniques
 - Conventional methods
 - Pygmy meter
 - AA meter
 - ADV's
 - ADCP's
 - Flumes
 - Weir plates
 - Volumetric
 - Floats

Procedure for Conventional Current-Meter Measurement of Discharge

- Select measurement cross section meeting as many of the following criteria as possible:



Ideal Cross-Section Characteristics

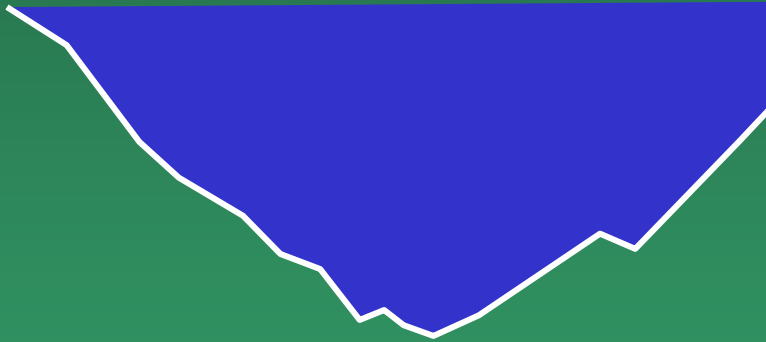
1. Cross section lies within a straight reach, and streamlines are parallel to each other.
2. Velocities are greater than 0.5 ft/s (0.15 m/s) and depths are greater than 0.5 ft (0.15 m).
3. Streambed is relatively uniform and free of numerous boulders and heavy aquatic growth.
4. Flow is relatively uniform and free of eddies, slack water, and excessive turbulence.

An Ideal Cross Section



The Velocity-Area method

Discharge = (Area of water in cross section) \times (Water velocity)



\times

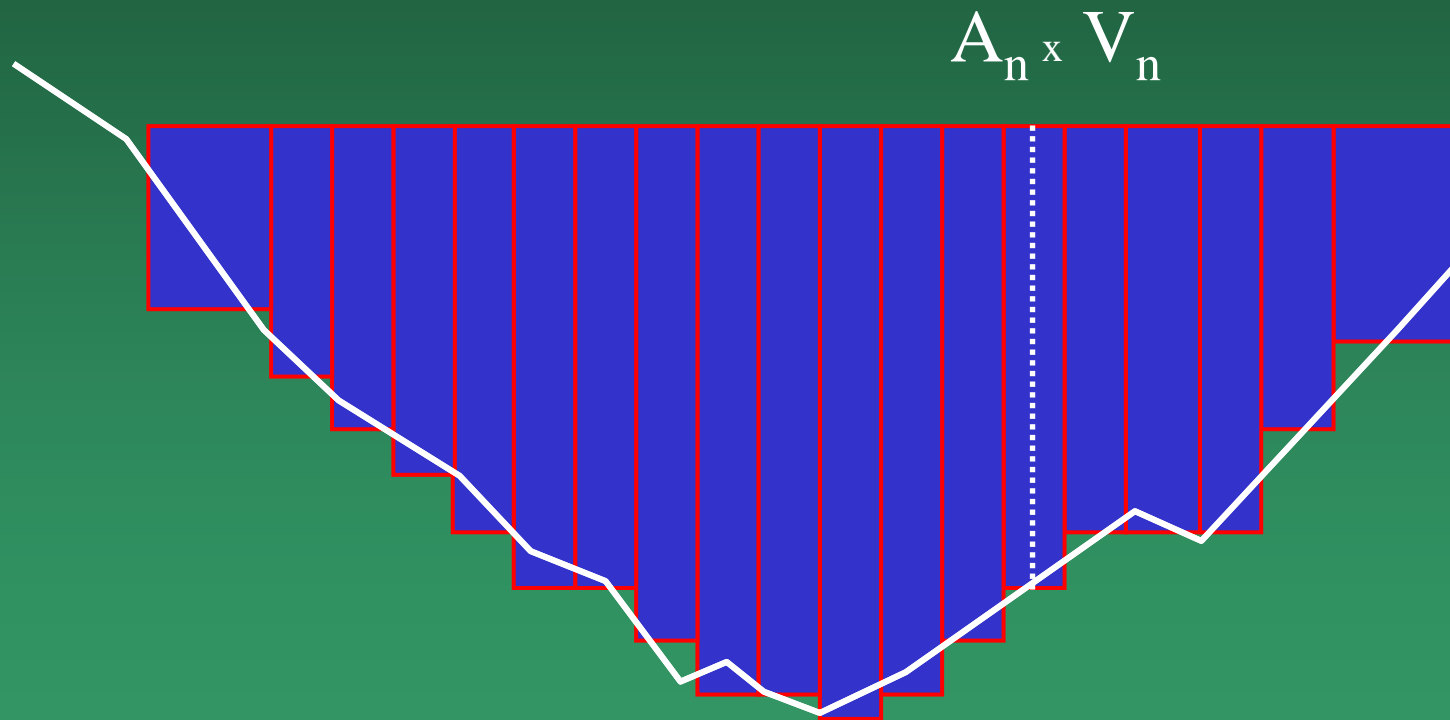
Water Velocity

Cross-section area



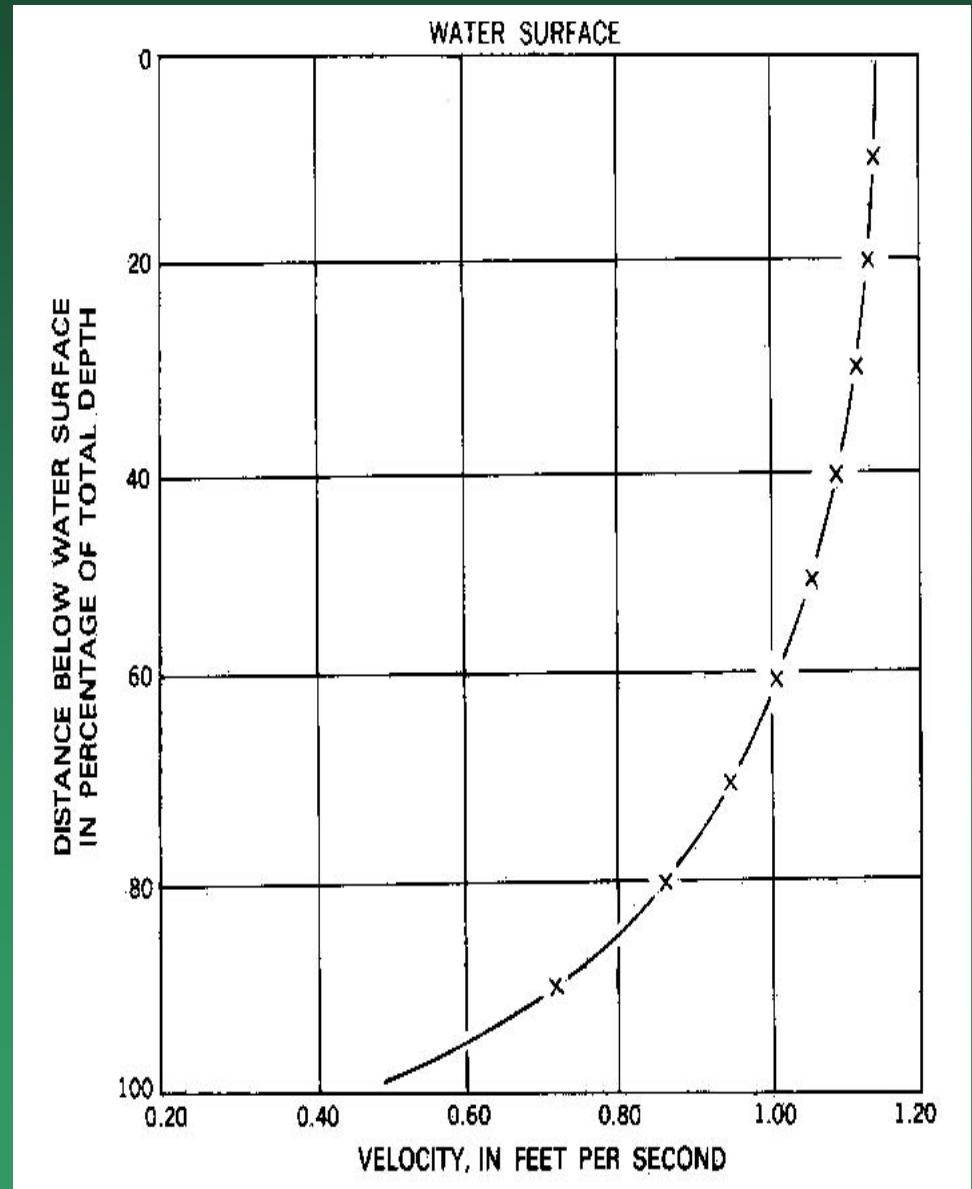
Total discharge is sum of sub-section discharges (mid-section method)

$$\text{Total Discharge} = ((\text{Area}_1 \times \text{Velocity}_1) + (\text{Area}_2 \times \text{Velocity}_2) + \dots (\text{Area}_n \times \text{Velocity}_n))$$



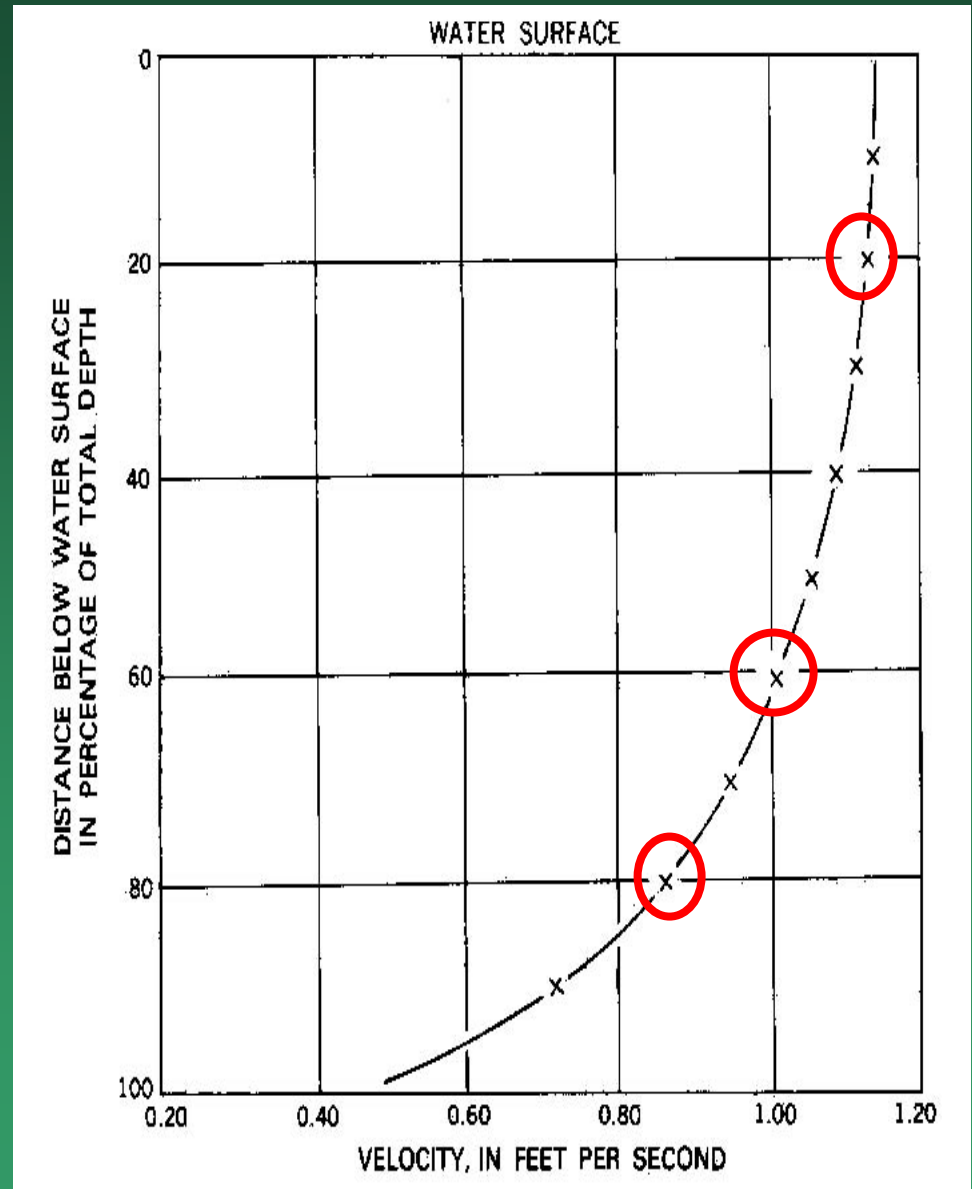
Vertical-Velocity Curve

- The vertical-velocity profile under normal conditions tends to have the shape shown at right. We can use this relation to compute a mean vertical velocity based on measurements at certain points in the vertical.



Vertical-Velocity Curve

- The average velocity of the vertical typically can be accurately estimated by the 2-point method, with velocity measurements made at 0.2 and 0.8 of the depth below the surface.
- The 0.6-depth method is used when depths are too shallow for the selected meter.



Pygmy Meter

- 0.3 to 1.5 ft recommended depth.
- 0.6-depth method used for depths > 0.3 ft & < 1.5 ft
- Large errors < 0.25 or > 3.0 ft/s



Price AA Meter

- >1.5 ft depth.
- 0.6-depth method used for depths >1.5 ft & <2.5 ft
- 2-point method used for depths > 2.5 ft
- Large errors <0.25 or >8.0 ft/s



Current-Meter Measurement by Wading

- The hydrographer should stand in a position that **least affects the velocity of the water passing the current meter:**
- That position is usually obtained by facing the bank so that the water flows against the side of the leg. The wading rod is held at the tag line by the hydrographer who stands about 3 in. downstream from the tag line and at least 1.5 ft. from the wading rod.



Current-Meter Measurement of Discharge from Bridges or Cableways

- If the stream cannot be waded and the measurement must be made from a cableway, a bridge, or a boat, the measurement section selected should still have the attributes listed above.
- The AA meter is typically used, with a sounding weight.



Current-Meter Measurement from Bridges or Cableways

- The size of the sounding weight used in current-meter measurements depends on depth and velocity in the cross section.
- The size of the weight (lb) should be **greater than the maximum product of velocity (ft/s) and depth (ft) in the cross section.**
- If insufficient weight is used, the meter assembly will be dragged downstream, and will result in errors in the depth computation.



Current-Meter Measurement from Bridges

- Either the upstream or downstream side of the bridge can be used for making a discharge measurement. The advantages of the upstream side are:
 1. Hydraulic characteristics at the upstream side of bridge openings usually are more favorable.
 2. Approaching drift can be seen and thus can be more easily avoided.
 3. The streambed at the upstream side of the bridge is not likely to be scoured as badly as the downstream side.

Current-Meter Measurement from Bridges

- The advantages of using the downstream side of the bridge are:
 1. Vertical angles are more easily measured because the sounding line will move away from the bridge.
 2. The flow lines of the stream may be straightened by passing through a bridge opening with piers.
- Measurement location should be decided individually for each bridge after considering the above factors.

Useful Guidelines for Conventional Current-Meter Measurement of Discharge

- Divide cross section into 25-30 sections
 - Ideally no more than 5% of total flow in any section.
- Select the meter according to cross section conditions.
- Make velocity measurement at each measurement point in the vertical for 40-70 seconds.
- Collect accurate depth measurements
 - Compensate for soft or algae-covered stream bottoms
- Do not move upstream or downstream from the tagline to avoid stream bottom irregularities
- If depths or velocities under natural conditions are too low for a dependable current-meter measurement, **the cross section should be modified**, if practical, to provide acceptable conditions, for example by building temporary dikes or by removing rocks and debris.

Care and Maintenance of Mechanical Meters

- Examine for damage, wear or faulty alignment before and after use.
- Clean and oil after use.
- Separate pivot and pivot bearing when not in use.
- Store in secure container when not in use.
- Spin test between field trips, when performance is suspect, and before and after repairs.
 - Minimum spins
 - 0:45 min for pygmy meter
 - 2:00 min for AA meter
- Maintain current-meter log book
 - Include spin tests and maintenance info

Paradigm Shift

Mechanical Meters (Past and Present)



**Hydroacoustic Meters
(Present and Future)**



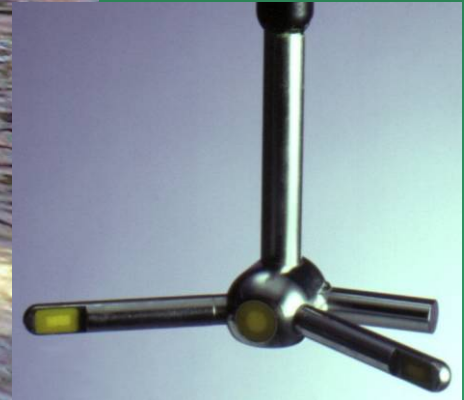
ADV's (aka FlowTrackers)

- ADV's: Acoustic Doppler Velocimeter
- Acoustic instruments that use the Doppler principle to perform high-resolution measurements of water velocities.
- Essentially an expensive current meter



FlowTrackers: Principle Benefits

- Accurate Low-Flow Measurements (shallow/slow)
 - 2 inches (.17 ft) from boundary.
 - 1% (reported) accuracy of 1 second velocity determinations over range of .003 to 15 ft/s
 - >0.17 ft recommended depth but can get accurate results much shallower with caution and patience
- No mechanical parts to maintain/fail
- Time savings/built in calculations
- One meter for all wading measurements
- Additional quality assurance parameters.



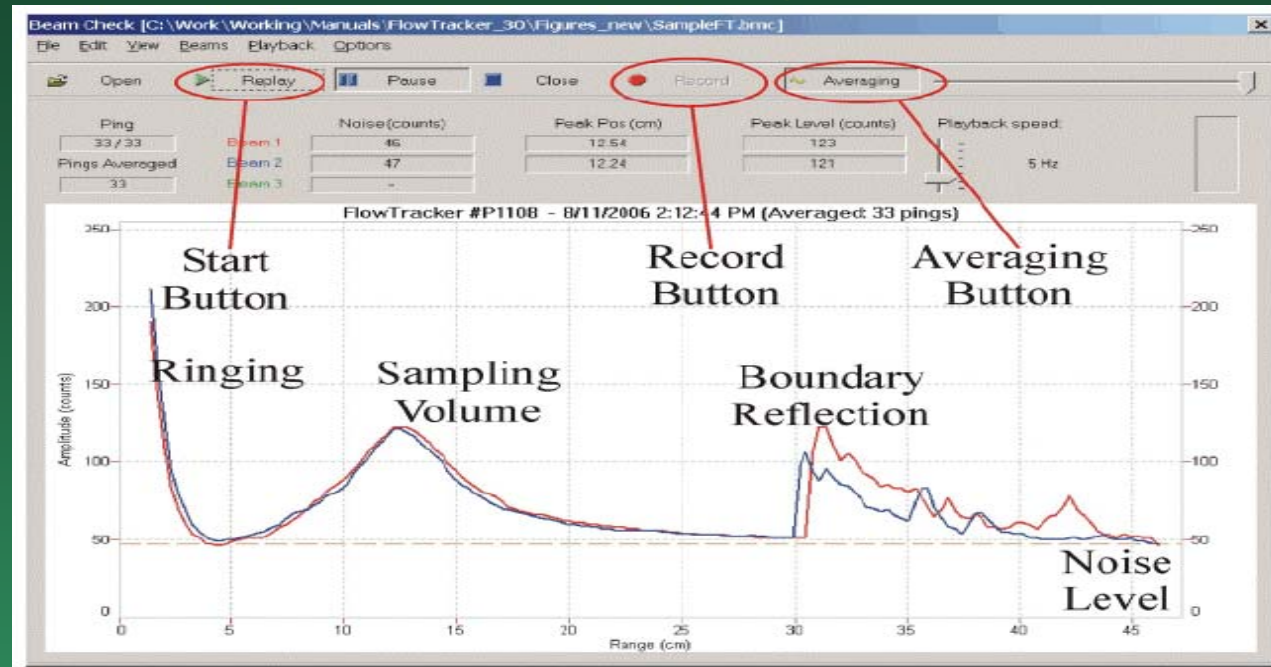
FlowTracker: Site Selection

- Site selection is just as important when making a Q measurement with a FlowTracker as any other method
- A good measurement site is:
 - Within a straight reach with parallel streamlines
 - A uniform streambed relatively free of boulders, debris or aquatic growth
 - Relatively uniform flow free of eddies, slack water, and excessive turbulence

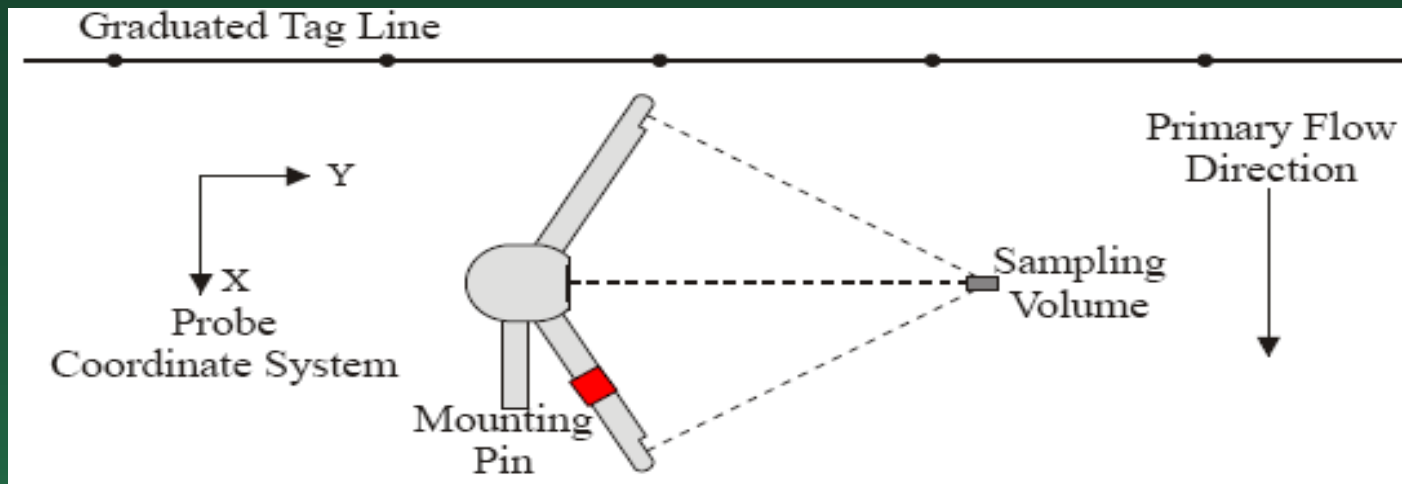
FlowTrackers: Location of velocity observations in each vertical

- Single-pt method (at 0.6 depth)
 - depths < 1.5 ft
 - depths between 1.5 and 2.5 when bed conditions prohibit 0.8 depth measurement (boundary warnings)
- 2-pt method (at 0.2 and 0.8 depths)
 - depths > 2.5 ft
 - depth between 1.5 and 2.5 ft if 0.8 depth sample location would be more than 2" from any boundary
- 3-pt method (at 0.2, 0.6, and 0.8 depths)
 - If a non-standard profile is discovered while using the 2-pt method

FlowTrackers: Office Diagnostics



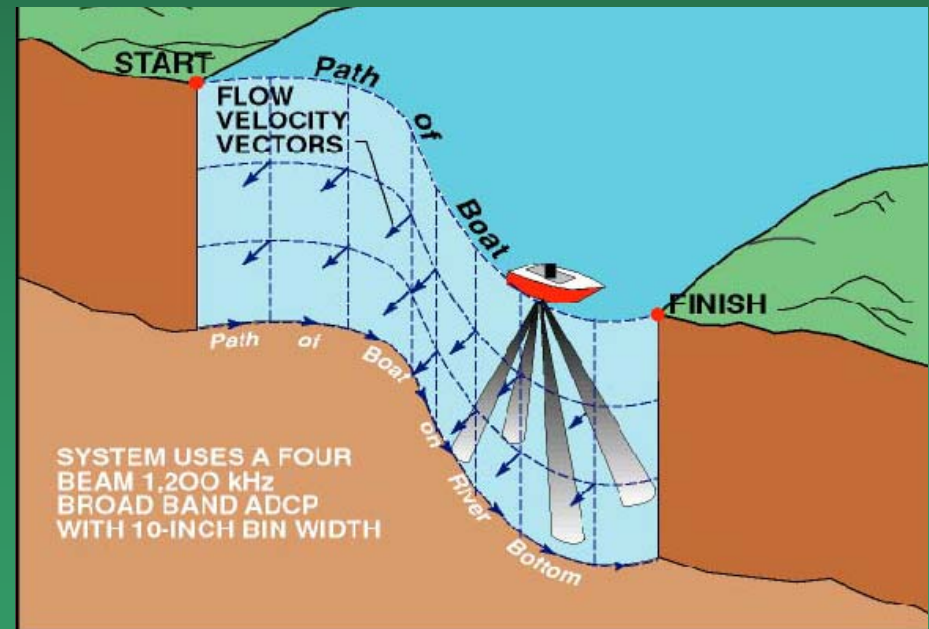
- BeamCheck is the FlowTracker's diagnostic software.
- Should be run prior to each week of use at a minimum.
- An automatic test can be run prior to each measurement in the field, but does not take the place of this requirement.



- The X velocity component as shown above is the only component of interest during a discharge measurement.
- The FlowTracker will compute that component automatically if it is oriented perpendicular to the tagline as shown above so that the pulse generated by the transmitter is parallel to the tagline.

ADCP (Acoustic Doppler Current Profiler)

- Faster on larger streams and more accurate than conventional methods, but requires more training.
- Applicable in many environments and hydraulic conditions
- Expensive investment



ADCPs: Applications



Other Flow Measurement Methods

- Weir plates
- Portable Flumes
- Volumetric
- Floats

Portable Weir Plate

- A portable weir plate is a useful device for determining discharge when depths are too shallow and velocities too low for a reliable current-meter measurement of discharge. A 90 degrees V-notch weir is particularly suitable because of its sensitivity at low flows.
- The weir plate is made of galvanized sheet iron. The 90 degree V-notch that is cut in the plate is not beveled but is left with flat, even edges.

Portable Weir Plate

- A staff gage, attached to the upstream side of the weir plate with its zero at the elevation of the bottom of the notch, is used to read the head on the weir.
- A large weir plate can measure discharges in the range from 0.02 to 2.0 ft³/s, with an accuracy of +/- 3 percent if the weir is not submerged.
- The weir plate must be level and flow allowed to equilibrate after installation.



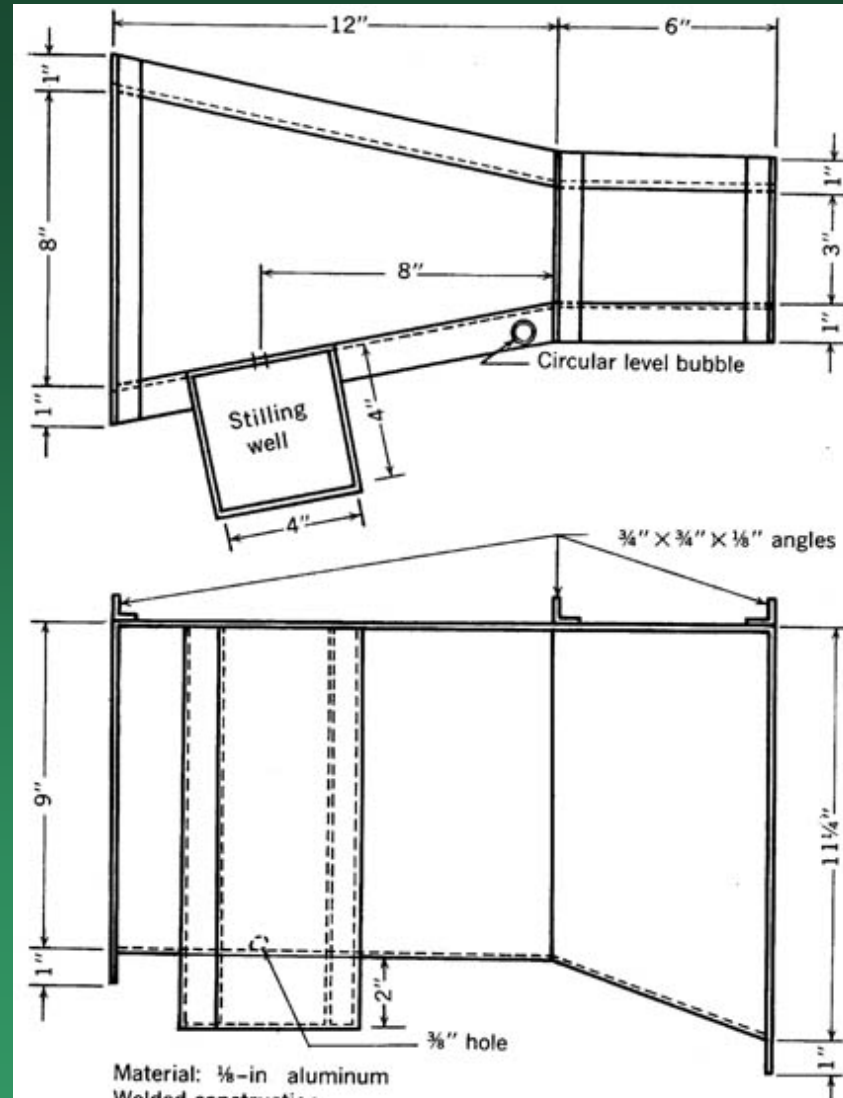
Portable Parshall Flume

- Another device for determining discharge when depths are too shallow and velocities too low for a current-meter measurement of discharge.



Portable Parshall Flume

- The gage height or upstream head on the throat is read in the small stilling well that is hydraulically connected to the flow by a $\frac{3}{8}$ in. hole.



Material: $\frac{1}{8}$ -in aluminum

Welded construction

Note: This stilling well can accommodate a 3-in float and be used with a recorder if continuous measurement is desired for a period.

Portable Parshall Flume

- Flume must be level
- Pack material around flume to prevent leakage
- Record gage height after pool reaches stable level!
- Careful measurement ± 2 or 3 percent.



Volumetric Measurement

- Applicable for small discharges, but is the most accurate method of measuring such flows, including seeps and springs.
- May be necessary to divert flow of a seep or spring into a pipe or modified channel for collection
- Discharge calculated with the time required to fill a container of known capacity
- Should repeat the measurement several times and average the results



Floats...the method of last resort

- Useful for measuring discharges when conventional methods are impractical.
- Floats may be almost any distinguishable article that floats, such as wooden disks; bottles partially filled with either water, soil, or stones; or oranges, floating ice cakes or distinguishable pieces of drift.
- Ideally, the float penetrates a substantial fraction of the total depth.
- Float cannot be allowed to contact the streambed.

Floats

- Two cross sections are selected along a reach of straight channel. The cross sections should be far enough apart so that the time the float takes to pass from one cross section to the other can be measured accurately.
- A number of floats should be distributed uniformly across the stream width. A stopwatch is used to time their travel.
- Compute discharge using subsections, as with the conventional discharge method.
- Repeated measurements should be made and averaged.

Measurement Environments

Environment	Characteristics	Recommended Method(s)
Rivers	Variable depth (>1.5 ft), very slow velocities	<ul style="list-style-type: none"> • ADCP • Floats • Possibly AA
Rivers	Variable depth (>1.5 ft), fast velocities	<ul style="list-style-type: none"> • AA or ADCP
Larger Streams	Variable depth and flow	<ul style="list-style-type: none"> • ADV • Pygmy or AA • ADCP
Small Streams	Shallow, variable flow	<ul style="list-style-type: none"> • ADV • Pygmy
Very Small Streams/Springs/Seeps	Shallow, diffuse or channelized flow	<ul style="list-style-type: none"> • Volumetric • Flumes • Weirs • Floats

Additional Resources

- S. E. Rantz and others, MEASUREMENT AND COMPUTATION OF STREAMFLOW VOLUME 1. MEASUREMENT OF STAGE AND DISCHARGE VOLUME 2. COMPUTATION OF DISCHARGE, USGS Water Supply Paper 2175 (<http://pubs.usgs.gov/wsp/wsp2175/>)
- Various USGS Office of Surface Water Memorandums (<http://water.usgs.gov/osw/pubs/memo.summaries.html>), including
 - 89.07 Policy to ensure the accurate performance of current meters
 - 99.06 Care and maintenance of vertical-axis current meters
 - 02.02 Policy and Technical Guidance on Discharge Measurements using Acoustic Doppler Current Profilers
 - 05.05 Guidance on the use of RD Instruments StreamPro Acoustic Doppler Profiler
 - 06.02 Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers (Scientific Investigations Report 2005-5183)
 - 07.01 Sontek/YSI FlowTracker firmware version 3.10 and software version 2.11 upgrades and additional policy on the use of FlowTrackers for discharge measurements.

Additional Resources....cont

- USGS Office of Surface Water Information
<http://water.usgs.gov/osw/>
- USGS Office of Surface Water on-line training resources
(<http://wwwrcamnl.wr.usgs.gov/sws/SWTraining/Index.htm>)
- USGS Water Science Center Directors (by state)
(http://water.usgs.gov/district_chief.html)